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ABSTRACT

This manual is designed to assist aerial pesticide applicators to meet the requirements of the Michigan Department of Agriculture for certification. An introduction with the explanation of requirements of effective aerial application is presented. The six topics included describe: (1) Dispersal equipment; (2) Calibration; (3) Pattern testing; (4) Operations; (5) Protecting the environment; and (6) Safety precautions. A list of self-help questions and instructions for completing the questions are presented at the end of the manual. (HM)

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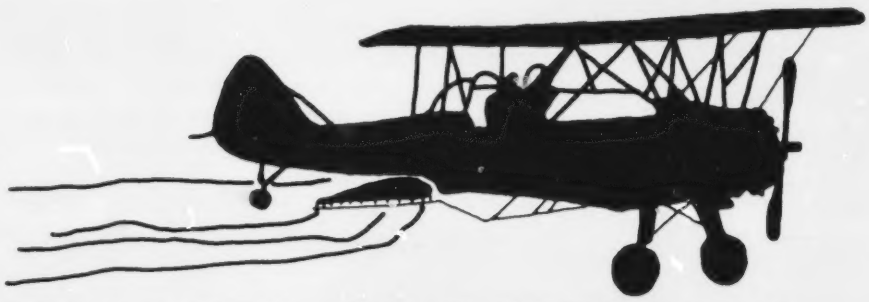
Aerial Application of Pesticides



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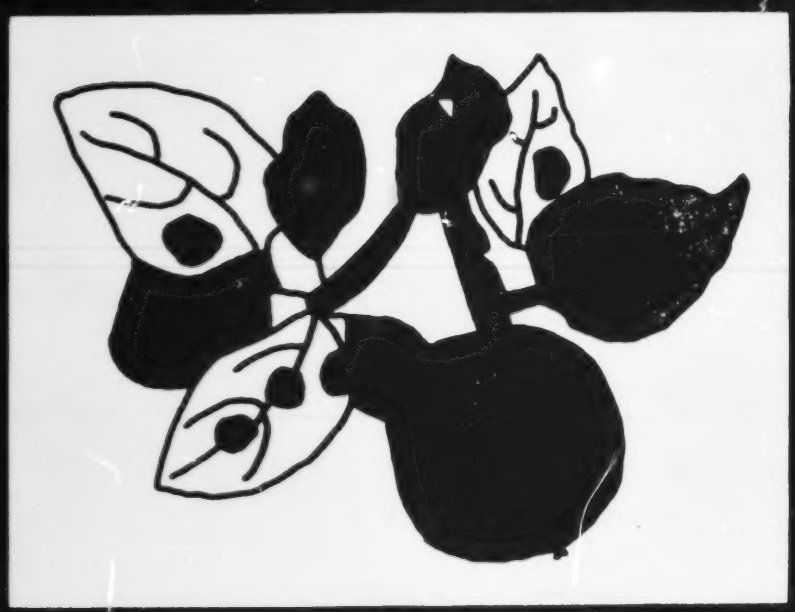
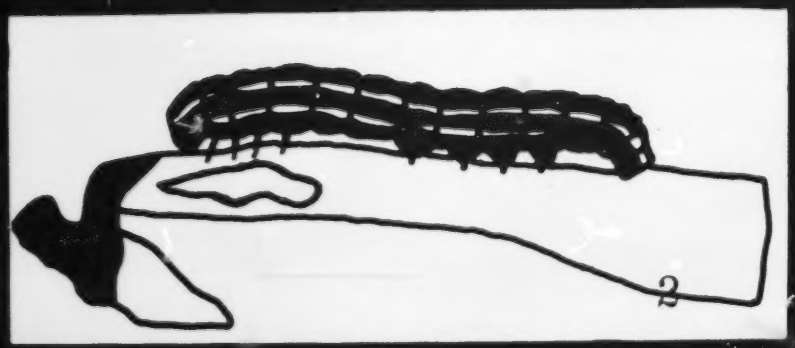
A MANUAL FOR COMMERCIAL APPLICATORS





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Aerial Applicators

Extension Bulletin 1032-11

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A list of self-help questions and instructions for completing the questions are at the end of each section. If you encounter difficulties in using the manual, please consult your county agricultural extension agent or representative of the Michigan Department of Agriculture for assistance.

Some suggestions on studying the manual are:

1. Find a place and time for study where you will not be disturbed.
2. Read the entire manual through once to understand the scope and form of presentation of the material.
3. Then study one section of the manual at a time. You may want to underline important points in the manual or take written notes as you study the section.
4. Answer, in writing, the self-help questions at the end of the manual. Instructions on how to use the self-help questions in your study are included with the questions. These questions are intended to aid you in your study and to help you evaluate your knowledge of the subject. As such, they are an important part of your study.
5. Reread the entire manual once again when you have finished studying it all. Review with care any sections that you feel you do not fully understand.

This manual is intended to help you use pesticides effectively and safely when they are needed. We hope that you will review it occasionally to keep the material fresh in your mind.

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INTRODUCTION

Effective aerial application requires:

- close cooperation between applicator and grower when planning a job,
- consideration of the effects of the environment;
- consideration for the safety of people, animals, and nontarget crops;
- correct and well-maintained equipment;
- accurate and uniform application;
- a competent pilot; and
- adherence to the planned procedure.

Limitations of aerial application are:

- need for correct weather conditions,
- difficulty in treating areas containing obstructions,
- difficulty in treating small or irregularly shaped areas, and
- long ferrying distances.

DISPERSAL EQUIPMENT

Both fixed- and rotary-wing aircraft are used for aerial application. Metering and dispersal equipment on the aircraft must meter correct quantities of pesticide formulations and deliver them uniformly. The equipment must be accurate so it can be calibrated correctly.

Liquid Systems

Liquid dispersal systems consist of:

- tank,
- agitation system,
- pump,
- piping and fittings,
- filters (screens),
- boom, and
- nozzles.

These systems may be wind-driven or they may be hydraulic or mechanical, powered by the aircraft engine.

Tank: The tank should be leakproof and corrosion-resistant. It should have a mechanism for emptying the contents quickly in the case of emergency. The aircraft must have a guage that measures tank contents. The tank should be fitted with an air vent--a tube type or a spring-loaded flapper valve.

Agitation system: Most pesticide formulations require some form of agitation during application.

Pump: The pump system must be able to deliver large quantities of liquid material per unit of time. Wind-driven pumps must have a workable brake.

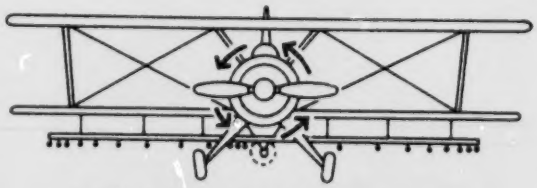
Piping and fittings: Main piping and fittings should have a large diameter (approximately 2 inches) in order to apply high volumes of liquids, and a smaller diameter (approximately 1 inch) for low-volume application. Smaller piping is adequate on helicopters because of their slower application speed.

Filters: Correctly sized line filters and nozzle filters (screens) will prevent nozzle clogging. Screen sizes range from 20 to 100 mesh, according to the size of the nozzle opening (larger mesh (20) for larger nozzles). Screens should be located between the tank and pump or between the pump and the boom.

Boom: The boom supports and supplies the nozzles. When the boom is located near the trailing edge of the wing, clearance between control surfaces of the wing and the boom is essential. End caps on the boom make it easier to flush the boom and nozzles. The boom should have a positive shut-off valve.

Nozzles: Special nozzles are available for use in aircraft systems. They must be equipped with an antisiphon or nondrip check valve. Manufacturer's specifications will guide you in your choice. A uniform spray pattern depends on correct nozzle placement on the boom.

The spray pattern shifts in the direction of propeller rotation. Adjusting the distance between the nozzles on the boom helps to correct this problem (see illustration below). Placing end nozzles inboard will prevent the wingtip vortex from trapping fine droplets, causing uneven distribution and drift.

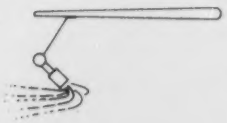


Front View of Variable Distance Nozzle Placement

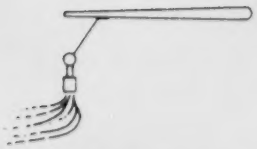
Nozzle placement on a helicopter boom may be uniform except where the spray may hit parts of the aircraft such as the skids. A rear section boom is sometimes used to help keep spray off the helicopter. The angle of the nozzle in relation to the direction of travel affects droplet

size (see illustration below). Flight speed also has an effect on the size of droplets.

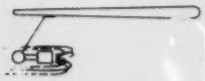
This nozzle position produces coarse droplets



This nozzle position produces fine droplets



This nozzle position produces medium droplets



Not this (spray collects on structure)

ULV Systems

Ultra low volume (ULV) spraying requires a special liquid dispersal system. Manufacturers can supply specifications for ULV systems. Few pesticides are labeled for ultra low volume aerial application.

Dry Systems

These systems may be used for applying dry formulations such as dusts, granules, and baits. The application equipment and the size, shape, density, and flowability of the materials affect swath width and pattern. The hopper must have walls, steep enough to ensure uninterrupted flow, and have a lid that will close tightly. An agitator will keep fine materials from bridging. The air vent should be either a spring-loaded flapper valve or tube type. An adjustable gate is frequently used to regulate flow rate. It must have a tight seal when closed. and is not leaking.

CALIBRATION

Calibration is adjusting your equipment to apply the desired rate of pesticide. Calibration is especially important in aerial application, since large areas are covered in a short time. Calibrate often to be sure that the equipment is adjusted correctly.

Liquid Systems

Here are the basic steps in sprayer calibration:

- Determine the acres your aircraft's system treats per minute at the speed and height you plan to fly.
- Figure the gallons you must spray per minute to apply the recommended rate.
- Select the size and number of nozzle tips which will deliver the correct number of gallons

per minute at the operating pressure of your system. Use the nozzle manufacturer's specifications as a guide.

- Make a trial run.
- Determine the amount of chemical to add to the tank.

The following example will explain these basic steps. Your aircraft has a 300-gallon tank. The effective swath width is 50 feet. You plan to spray at 100 mph at a height of 8-10 feet. The chemical is to be applied at the rate of 1 pint per 3 gallons of spray per acre. The operating pressure will be 40 psi.

- Determine acres per minute covered.

Acres per minute =

$$\frac{2 \times \text{swath width (ft.)} \times \text{speed (mph)}}{1{,}000}$$

In our example, $\frac{2 \times 50 \times 100}{1{,}000}$ = 10 acres per minute

The table below will tell you the acres covered per minute when swath width and aircraft speed are known.

Acres Per Minute for Various Speeds and Swath Widths

Speed	*Swath Width (Feet)*							
(mph)	*30*	*35*	*40*	*45*	*50*	*75*	*100*	*200*
40	*2.4*	*2.8*	*3.2*	*3.6*	*4.0*	*6.0*	*8.0*	*16.0*
50	*3.0*	*3.5*	*4.0*	*4.5*	*5.0*	*7.5*	*10.0*	*20.0*
60	*3.6*	*4.2*	*4.8*	*5.4*	*6.0*	*9.0*	*12.0*	*24.0*
70	*4.2*	*4.9*	*5.6*	*6.3*	*7.0*	*10.5*	*14.0*	*28.0*
80	*4.8*	*5.6*	*6.4*	*7.2*	*8.0*	*12.0*	*16.0*	*32.0*
90	*5.4*	*6.3*	*7.2*	*8.1*	*9.0*	*13.5*	*18.0*	*36.0*
100	*6.0*	*7.0*	*8.0*	*9.0*	*10.0*	*15.0*	*20.0*	*40.0*
110	*6.6*	*7.7*	*8.8*	*9.9*	*11.0*	*16.5*	*22.0*	*44.0*
120	*7.2*	*8.4*	*9.6*	*10.8*	*12.0*	*18.0*	*24.0*	*48.0*

- Determine gallons per minute (gpm) required in our example, ex10=30 gallons per minute. Be sure your pump can deliver this volume.
- Select the nozzles. First determine the gpm per nozzle that would deliver the required 30 gpm flow. Most agricultural aircraft booms can accommodate about 40 nozzles, but most applicators prefer to use the smallest number that will provide a uniform pattern. Let's assume you choose to use 26 nozzles. The gpm per nozzle is determined this way:

$$\text{gpm per nozzle} = \frac{\text{gpm required}}{\text{number of nozzles}}$$

In our example, $\frac{30}{26}$ = 1.16 gpm per nozzle

You chose a pressure of 40 psi. Using the manufacturer's catalog, select a nozzle delivering 1.16 gpm at 40 psi. You may find that the nozzle closest to your needs delivers only 1.10 gpm. This small difference can be adjusted by increasing the pressure.

- Make a trial run to check the system. After installing 26 of the selected nozzles, make a trial calibration test flight to be sure you are spraying at the correct rate.

Fill the tanks with water to a known level on a level apron or strip. Fly the aircraft at the selected 100 mph airspeed and at the selected pressure for a timed period (60 seconds in this example). Bring the aircraft back to the same point and measure the amount of water needed to refill the tank to the original mark. Divide the number

of gallons used by the number of acres (10 in this example) treated to determine the gallons you are spraying per acre.

- Determine the amount of chemical to add to the tank.

Chemical per tank=acres per tankXchemical recommended per acre

$$\text{Acres per tank} = \frac{\text{gallons per tank}}{\text{gallons per acre}}$$

In our example, $\frac{300 \text{ gallons per tank}}{3 \text{ gallons per acre}}$ = 100 acres per tank

100 acres per tankX1 pint per acre = 100 pints (12.5 gallons) per tank

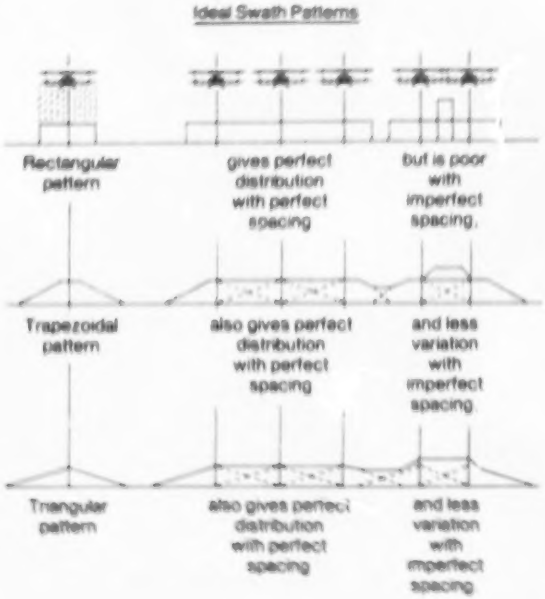
Dry Systems

Make several test flights with the spreader installed to determine the quantity of material metered out for a given gate setting. Helicopters may use electric or hydraulic air blowers and the material can be caught and measured while running up on the ground. You should use inert (blank) granules of the same size and density as those in the formulation to be applied. Operate the spreader for a measured period of time (at least 30 seconds). Weigh the quantity needed to refill the hopper. It may take three or more trial gate settings to determine the one that will give the required discharge in pounds per minute of granular material. To find the pounds per acre being applied, divide the pounds per minute.

PATTERN TESTING

Check the swath pattern to make sure the distribution across the swath is as uniform as possible. Both helicopters and fixed-wing aircraft create wind currents (vortices) that affect the swath pattern. The tests must duplicate the airspeed, height of flight, spray pressure, and nozzle angle and placement or gate settings that will be used for the actual application. Make pattern tests in calm air (winds less than 3 mph) to avoid distortion caused by crosswinds. The best way to test a liquid pattern is to add a tracer (dye or fluorescent material) to the water in the tank(s) of the aircraft. For dry pattern testing, use a blank (nontoxic) material with properties similar to the formulation to be applied. Collect the test material on paper (for liquids) or in buckets (for dry materials) placed across the flight path on the ground. Observation of the collected materials will show the actual swath pattern.

A rectangular pattern gives perfect distribution if flight swaths are spaced perfectly. The trapezoidal and triangular patterns are better, however, because they allow for some error in spacing swaths. They give uniform distribution across the field except for the first and last swaths.


Ideal Swath Patterns
Rectangular pattern
gives perfect distribution with perfect spacing
but is poor with imperfect spacing.
Trapezoidal pattern
also gives perfect distribution with perfect spacing
and less variation with imperfect spacing
Triangular pattern
also gives perfect distribution with perfect spacing
and less variation with imperfect spacing

OPERATIONS

General

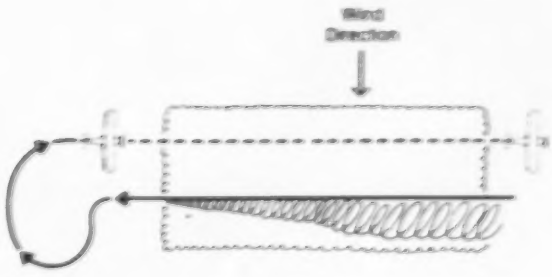
When an aircraft has been calibrated, the airspeed, spraying pressure (or gate setting for dry materials), height of flight, and effective swath width are fixed. Applications must be made at the same settings.

Pressure

Pressure should be around 40-50 psi (pounds per square inch). Choose the pressure near this range that will combine with your selected swath width, airspeed, and nozzle type to give the correct rate of application and desired droplet size. With most nozzle types, droplet size decreases as pump pressure increases. Use pressure gauges to indicate boom or pump pressure.

Field Flight Patterns

For retangular fields, fly back and forth across the field in parallel lines. Flying parallel to the long axis of the field will reduce the number of turns. For pilot safety, start treatment on the downwind side of the field if there are low-speed crosswinds. This prevents flying through the previous swath. (See diagram below.) To prevent skips and drift, stop flying if wind speed increases excessively.



If the area is too rugged or steep for this pattern, flight lines should follow the contours of the slopes. When the area is too deep for contour work, make all applications downslope.

Swath Marking

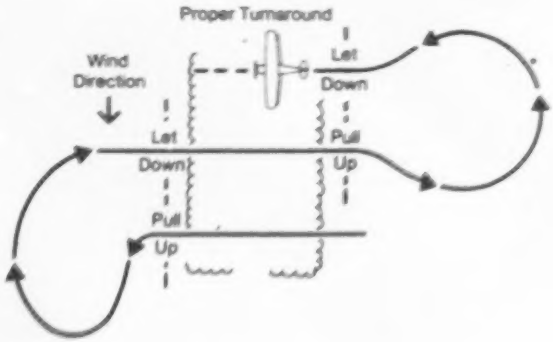
Swaths can be marked with permanent or semipermanent flags set above the height of the crop to guide the pilot. This method is useful if the field will be treated several times a season.

Two flagmen can help the pilot line up on the field. When the pilot has lined up on his swath, the nearer flagman starts pacing off (or counting crop rows) to the next swath. Flagmen should avoid being directly sprayed on, and they should never turn their backs toward an oncoming aircraft. When the aircraft is being flown parallel to a row crop, one flagman can identify the swath row for the pilot.

Automatic flagmen are often used. These devices, attached to the aircraft and controlled by the pilot, release weighted streamers. The streamers give the pilot a visible mark to help him judge the next swath. Helicopters on small field applications may not need flagmen. Their short turnarounds allow them to locate the next swath easily.

Turnaround

At the end of each swath, the pilot should shut off the dispersal equipment and pull up out of the field before beginning his turn. Complete the turn soon enough to permit slight course corrections before dropping into the field again for the next swath (see diagram below).



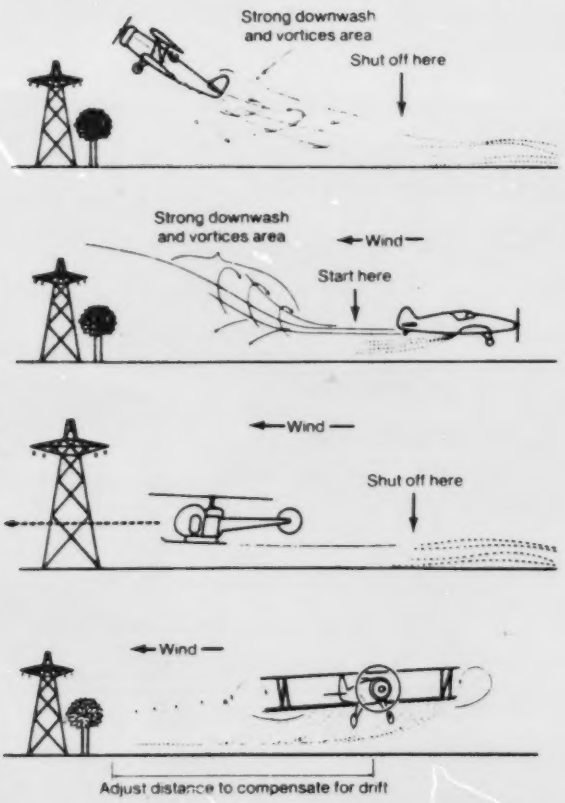
Obstructions

If there are obstructions (trees, power and telephone lines or buildings) outside the field at the beginning or end of the swath, turn the equipment on late or shut it off early. When the field is completed, fly one or two swaths crosswise (parallel to the obstruction) to complete the job.

Obstructions inside the field should be treated in the same way. Skip the area around the obstruction and spot treat it later.

Areas next to buildings, residences, livestock, nontarget crops or waterways should be treated with caution:

- Fly parallel to the sensitive area.
- Leave a border of untreated crop to avoid possible drift onto the area.
- Avoid making turns over dwellings where possible.



PROTECTING THE ENVIRONMENT

Controlling Drift

Drift is the airborne movement of spray, granule, or dust particles to places other than the target area. Properly controlled drift may help the pesticide reach the target. Drift is harmful when it causes damage in nontarget areas.

The main factors that must be considered in controlling drift are discussed below.

Droplet size: Droplet size is one of the most important factors affecting drift. Small droplets are a much greater drift hazard than large droplets. Small droplets stay in the air longer because they fall more slowly, and they are more easily carried by wind currents because they are lighter.

Pesticide spray systems cannot produce a completely uniform droplet size. Rather, they produce a range of droplet sizes.

Nozzle type and pressure are important factors affecting droplet size. In general, the size of droplets decreases as the size of the nozzle opening decreases or the pressure increases.

The position of nozzles on the boom also affects droplet size (see equipment section).

You can get chemical adjuvants which affect droplet size:

- Thickening agents may be added to spray mixtures to create larger spray particles. However, the airstream may break these large droplets into smaller ones.
- Surfactants are sometimes added to spray solutions to create smaller droplets, improve coverage, and increase wettability of the spray. Be sure that droplets are not so small that they create a drift problem.

A measurement of nozzle performance is the Volume Median Diameter (VMD) of the droplets it produces. The VMD is the droplet diameter that satisfies the condition that half of the spray volume consists of drops larger and half consists of drops smaller.

Drift Distance of a 2.8% Oil/Water Emulsion Applied During Strong Temperature Inversion at Boom Height of 5 feet and Wind Speed Less Than 5 mph.

Final VMD (micrometers)	*Distance Downwind (feet)*
400	*50*
200	*150*
100	*400*
50	*1320 (1/4 mile)*

Weather: Droplet size is one of the most important factors affecting drift. Small droplets are a much greater drift hazard than large droplets. Small droplets stay in the air longer because they fall more slowly, and they are more easily carried by wind currents because they are lighter.

Pesticide spray systems cannot produce a completely uniform droplet size. Rather, they produce a range of droplet sizes.

Nozzle type and pressure are important factors affecting droplet size. In general, the size of droplets decreases as the size ot the nozzle opening decreases or the pressure increases.

An inversion layer exists in still air that:

- is coolest at the ground level,
- gets warmer up to a certain height, and
- gets cooler from that point on up.

Particles released into the cool air layer at ground level during an inversion have a minimum upward movement. The slightest air movement can cause this mass of particles to drift for great distances before the particles fall.

A lapse exists when the air:

- is warmest at ground level, and
- gets continuously cooler at higher elevations.

During a strong lapse, the warm air near the ground rises, carrying very small pest cide particles with

it. An applicator should at least be aware of these two conditions, because sometimes they can be severe enough to cause serious drift problems.

Vaporization: Another type of pesticide movement is called vaporization (vapor drift)--the volatilization of an active ingredient during or after application. You must know which pesticides are highly volatile (evaporate easily). High temperatures or other climatic conditions may cause vaporization of some active ingredients. Apply them during periods of relatively low temperature and high humidity. Use active ingredients with low volatility where vaporization might cause problems.

Protecting Bees

Honey bees and other beneficial insects can be harmed by some pesticide applications. Beekeepers, aerial applicators, and their customers must cooperate closely to protect honeybees. You can reduce bee losses significantly by careful planning and good communications. Bees travel for long distances, so use of pesticides toxic to bees may affect hives outside the immediate vicinity of the treatment area. When using materials hazardous to bees, remind your customer to notify the beekeeper so that he may protect his bees. With few exceptions, dusts may be more hazardous to bees than sprays. Time of application is important and depends on blooming period and attractiveness of the crop. Treatment during the night and early morning before bees are foraging is the safest for the bees.

SAFETY PRECAUTIONS

General Precautions

- Wear protective clothing and equipment appropriate for the pesticide. The label on each pesticide specifies the protection required.
- Know the pesticide being applied and how to get emergency help if needed.
- Avoid all unnecessary contact with spray or dust.
- Change clothing and bathe after each day's work.

Pilot

- Avoid loading or handling highly hazardous pesticides. Exposure to toxic pesticides could cause illness that would make it unsafe to operate the aircraft.

The signs and symptoms of illness commonly include dizziness and constriction of the pupils of the eyes (myosis). Myosis impairs visual sharpness and can lead to fatal accidents. Direct eye contamination by organophosphate or carbamate pesticides may cause constriction of pupils for up to 7 to 10 days without any other symptoms. A pilot who has experienced any symptoms of pesticide poisoning should not fly until he has had medical clearance.

- Make preflight aircraft check.
- Check operation and calibration of dispersal equipment periodically.
- Check target area and surroundings for safety or drift hazards before application.
- Avoid flying through drift.
- Do not apply pesticides over flagmen or other persons. Use of permanent markers and automatic flagmen eliminates the possibility of harm to flagmen.
- See that members of the ground crew know their responsibilities and are acquainted with label precautions.
- Do not fly in a manner or at a time which may create a hazard--even if a customer insists.
- Warn all people in the treatment area about the application.

Ground Crew

- Close tanks and hoppers tightly after filling.
- Remove any spilled chemical.
- Clean aircraft, especially the cockpit, frequently.
- Where possible, clean equipment on a hard-surfaced apron so that runoff can be collected and disposed of safely.
- Do not stand in runoff water without appropriate protection or allow it to splash on you.

Flagmen

- Warn all people in the treatment area about the application.
- When the aircraft is lined up for a pass, move over to the next position.
- Do not turn your back on an approaching aircraft.
- Stay at the field until the pilot has completed the job so you can help if an accident occurs.

SELF-HELP QUESTIONS

Now that you have studied the manual, answer these questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them in the text. Erase your answer and write in the correct answer if your first answer is wrong.

1. What are some limitations of aerial application?

2. What size main piping and fittings should be used for high volume aerial applications?

3. Why should end nozzles be placed inboard on fixed wing aircraft?

4. Are there many pesticides available now for ULV spraying systems?

5. What are the basic steps in calibrating an aerial sprayer?

6. What are the basic steps in calibrating a dry system?

7. What is the advantage of having a triangular or trapezoidal application pattern?

8. Why should flight patterns be started on the downwind side of the field?

9. How can swaths be marked?

10. What should be done if buildings or residences are next to the area to be to be treated?

11. How does the size of the nozzle opening and pressure affect droplet size?

12. What does the term "volume median diameter" mean?

13. What is the effect of an inversion on drift?

14. Are dusts or sprays usually more hazardous to honey bees?

15. Where can information be found on the protective clothing needed when using a pesticide?

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